PCT/GB 00/03082

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| 2. | Patent application number *(The Patent Office will fill in this part)* | 9919100.9 — 12 AUG 1999 |
| 3. | Full name, address and postcode of the or of each applicant *(underline all surnames)* | SENTEC LTD<br>TERRINGTON HOUSE<br>13-15 HILLS ROAD<br>CAMBRIDGE<br>CB2 1GE |
| | Patents ADP number *(if you know it)* | 7353733002 |
| | If the applicant is a corporate body, give the country/state of its incorporation | ENGLAND |
| 4. | Title of the invention | IMPROVED TAG ~~CONSTRUCTION~~ READER |
| 5. | Name of your agent *(if you have one)* | c/o ANDREW HOWE |
| | "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* | SENTEC LTD<br>(as above) |
| | Patents ADP number *(if you know it)* | 7487606002 |
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DUPLICATE



# Improved Tag Reader

This invention relates to the field of passive magnetic data tags and readers. The invention is a reading system capable of reading tags with a plurality of magnetic elements, each of which may differ in coercivity, saturated dipole moment (i.e. response amplitude), orientation or bias field.

The authors have previously described magnetic tagging systems in PCT publication no GB2334183. This describes tags and reader systems primarily intended for tags fabricated from material of low coercivity, with elements at different orientations, in which data is recorded primarily by means of the orientation of the elements with respect to each other.

In this invention the authors present new methods to read tags that also store information by means of elements of differing coercivities, local bias fields and response amplitudes, showing how it is possible to build a general purpose tag-reading system for many different types of magnetic data tag. This includes the tags described in GB2334183, as well as tags described in, for example, US 5,204,526 (Fuji Electric Co), US 5,729,201 (IBM Corp) and WO 98/26312 (Flying Null).

These types of tags are interrogated by means of a time varying magnetic field. The system described in PCT GB2334183 uses algorithms to identify individual magnetic elements in a data tag by means of their order of appearance during a spiral magnetic scan, in which the normal vector to a rotating magnetic field traces out a spiral on the surface of a hemisphere. An algorithm is described in which the normal vector to the tag is determined by analysis of the variance of projected angles of the transition points of the elements on the tag plane. The system assumes that the coercivities of the tag elements are all the same, and are all very small compared to the interrogation field.

In this invention, we describe a system in which tags incorporating elements with significant coercivities can be read using new algorithms, in a system based on similar hardware to that described in GB2334183.

A specific embodiment of the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 illustrates a block diagram of the improved reader system

Figure 2 illustrates the tag and transition field directions for a tag with non-zero coercivity
Figure 3 illustrates the tag and transition field directions for a tag with both non zero coercivity and non-zero bias.

## Description of embodiment

The tag reading system is based on a system described in GB2334183 as a "3-D Reader Embodiment", with a number of important improvements. The coil arrangements are similar to those described in detail in GB 2334183, comprising a set of orthogonal transmit coils, outside a set of balanced orthogonal receiver coils.

Figure 1 illustrates the block diagram for this 3-D reader embodiment. A data acquisition card, 1, provides a multi-channel ADC/DAC facility. The card in mounted into an industry standard IBM-compatible PC. The data acquisition system, under software control, generates three transmit excitation voltages, at 13,16, 19, and these are amplified by three class D power amplifiers, 3, and drive three orthogonal transmit coils, 8, with resonating capacitors, 4, as shown. The transmitter currents are monitored by current sense resistors, 6, whose outputs are fed into the data acquisition system inputs, 14, 17 and 20. The instantaneous field vector can be determined from these three signals with knowledge of the relationship between the transmit coil field vs. current response. Signals detected from the tag by the three orthogonal receive coils, 9, are amplified, 10, and fed into the data acquisition system at inputs 15,18 and 21. A composite signal, 22, is also generated from these three signals using analogue weighting multipliers, 11, and an analogue adder, 12.

In the preferred embodiment, a continuous scan is used to interrogate the tag, based on a 130Hz rotating magnetic field, whose normal vector is arranged to trace out a spiral scan over the surface of a complete sphere, tracing a path from one "pole" to the other and back.

The data tag contains one or more elements that may differ in orientation, coercivity, response amplitude (dipole moment) and bias magnetisation. The objective of the scanning and decoding algorithm to determine the values of each of these properties, for each magnetic element, and thus to assign a code value to the tag. This is an improvement over the embodiment of the reader described in GB2334183, which did not distinguish response amplitude or coercivity.

**Element identification**

The composite signal, 22, is used to "gate" the receiver signals, 14.17, 20. Each time a zero crossing is detected, as described in GB2334183, the algorithm records that one or more magnetic element dipoles has flipped magnetisation. Each uniquely identified transition is recorded for further analysis. Data from a complete "spherical" scan is analysed in one pass.

Sequences of zero-crossings in which the number of transitions for each revolution of the interrogation field is equal to 2x the number of magnetic elements are particularly favoured, as these indicate regions of the data where element outputs do not overlap. Prior knowledge of the number of elements expected in the tag helps to determine these non-overlapping sequences.

**Preliminary Tag Normal Determination (for planar tags)**

For planar tags, the preliminary tag normal is determined by identification of the field vector (from inputs 14, 17 and 20) at which the largest "blip" in the composite signal, 22, occurs.

**Tag element distinction by orientation, coercivity and bias field**

In non-overlapping sequences, as described above, tag elements can be identified uniquely in multiple transitions, simply by looking at transitions that are separated by the number of elements.

Analysis of the individual input signals, 15, 18 and 21, at each transition determined from the composite signal, 22, yields a vector direction for the dipole element which has undergone the transition. This direction is independent of the coercivity of the element or the local bias field. Each element can give one of two vector directions for this transition, depending on which way round the transition is. The detection algorithm groups near-parallel (or anti-parallel) vectors together. The algorithm rejects vectors that do not match well in terms of dipole moment change or direction, as these may result from overlapping signals from adjacent elements. It also rejects signals that appear to lie well outside the estimated tag plane, based on the preliminary tag normal. This "rejection" function may be re-visited once a first approximation to the element directions has been obtained, as part of an overall iteration of the analysis.

The combination of non-overlapping sequences and identification of approximate tag normals from the receiver amplitude information allows signals from individual elements to be isolated from each other and grouped together. Some data will inevitably be discarded in this process – in particular, transitions that cannot be paired with at least one other transition. Some sets of data corresponding to the same tag element may not be associated with each other at this stage – the algorithm must be "cautious" in its association to avoid corrupting the subsequent analysis.

**Determination of Coercivity and Bias, given the Element Direction**

The description below explains the need to determine the tag element direction.

The coercivity may be determined by analysis of the angle between the transmit vector field and the tag element direction. With reference to Figure 2, elements with low coercivity, aligned in direction 24, will be expected to flip magnetisation which the field is aligned at 90°, 27, to the tag. Elements with non-zero coercivity will flip magnetisation when the field vector, rotating in sense 23, is in directions 25,26 to the element direction, 24, yet the receiver vector determined above will still line up with the element direction, 24. The coercivity of the element is given by the component of the field vector, 28, in the tag direction, 24, at the point when the tag flips magnetisation. The coercivities determined from field vectors 25, 26, will be equal in magnitude.

For an element with both coercivity and magnetic bias, Figure 3 shows the field vectors, 29 and 30, at which the element, aligned in direction 24, flips magnetisation states. In this case, the field values resolved in the direction of the tag, 31 and 32, are no longer equal and opposite. The sum of the magnitudes of 31 and 32 is equal to twice the coercivity, whilst the vector difference is equal to the bias field component in the direction of the tag element.

This analysis shows that determination of the individual element orientation is a key step in determining the tag element characteristics.

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## Tag Element Orientation Determination

The algorithm can treat each element entirely separately, since the receiver vectors and transition sequences have been used to separate signals for each element. For each element, an initial guess is taken as to the likely element direction, based on the mean value of the receiver vectors, determined above. For each transition, the component of the transmit fields along this "guessed" vector is determined. Typically, this will either be parallel or anti-parallel to the vector. The variances of the lengths of parallel and anti-parallel resolved values are determined separately and summed. A minimisation algorithm adjusts the direction of the element orientation vector to minimise this summed variance.

For an element with zero coercivity and no bias, the mean values of the parallel and anti-parallel resolved vectors will be close to zero.

For an element with non-zero coercivity and/or bias, the mean values of the parallel and anti-parallel resolved vectors will be equal to the resolved values, 31 and 32, in Figure 3. From these mean values, the element coercivity and bias along its length can determined from the sum and difference, as described above.

Data sets where the variances are unacceptably large are discarded, or split into subsets.

### Refinements

Once the orientations of all the elements have been determined, it is prudent to assess whether these elements occupy the same plane (assuming the tag is planar). The best fit normal to the plane can then be determined, and the tag vectors can be projected into the plane.

It is likely that multiple elements the same direction will be found at this point, because the earlier associations had not determined all the transitions associated with a single element. Some iteration of the minimisation process with the combined data is valuable at this point, followed by iteration of the best-fit normal determination.

The mean receiver amplitude response may also be determined at this stage, with preference being given to the response with more rapid field changes along the tag direction.

The methods described for anti-collision detection of multiple tags in GB2334183 are equally applicable to this situation. This leads to a reader system capable of identifying multiple spatially-separated tags in the same interrogation volume.

**Output of the Algorithm**

The basic algorithm outputs data for each magnetic element as follows:

Orientation in the reader (vector)
Coercivity of the element (scalar)
Bias field along each element (vector)
Amplitude response (scalar)

This data assumes little about the construction of the tag. The structure of the tag (e.g. which elements share bias magnet elements) may be used to provide more detail – for example, the magnitude and direction of an overall bias field. Finally, the details of the chosen coding scheme are used to translate these raw parameters into useful data stored on the tag.

## CLAIMS

1. A magnetic data tag reader capable of determining, independently, the orientation, the coercivity, the local bias and the amplitude response of each individual element.
2. A magnetic data tag consisting of a plurality of magnetic elements, in which element orientation, coercivity, bias and amplitude response are used to store data.

## ABSTRACT

This invention describes a magnetic data tag reading system capable of resolving multiple magnetic elements with differing coercivity, saturated dipole moment, orientation or bias field. A magnetic data tag constructed with a plurality of magnetic elements, differing by one or more of these factors, can be decoded by this system.

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| Pages of text | : | 6 |
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**Initial Application**

**INVENTION TITLE:**

**Improved Tag Reader**

# FIGURES

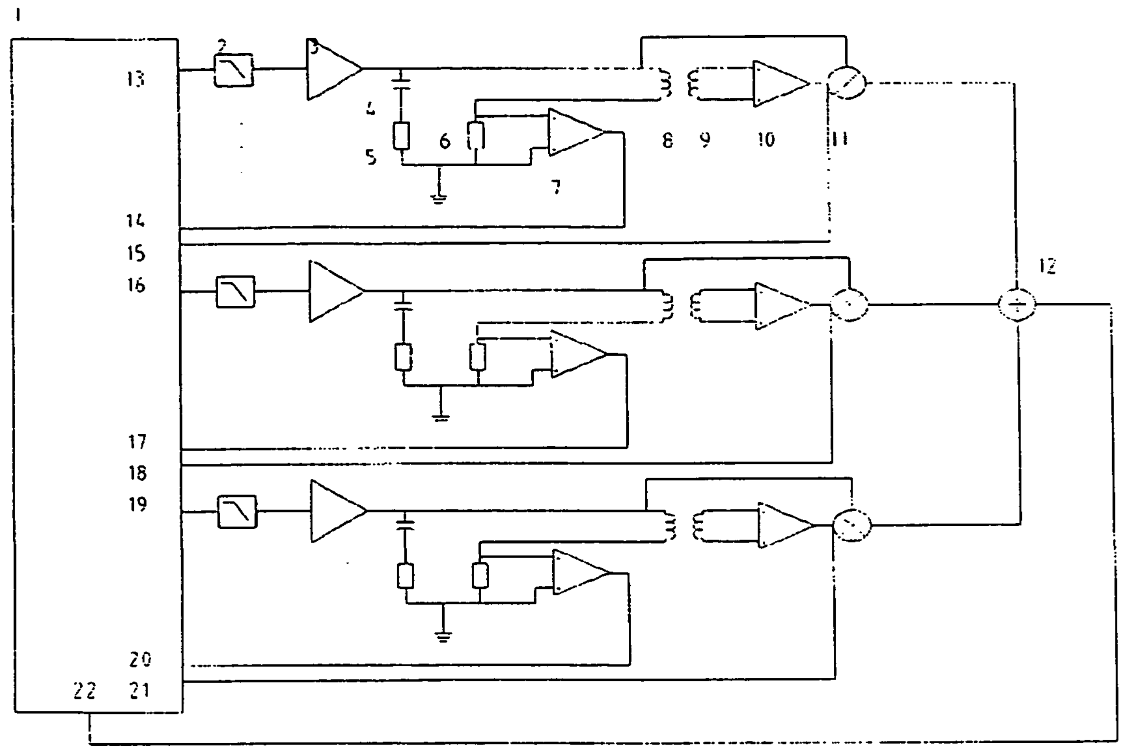


**Figure 1**

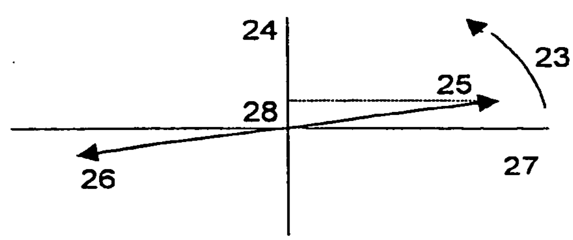


**Figure 2**

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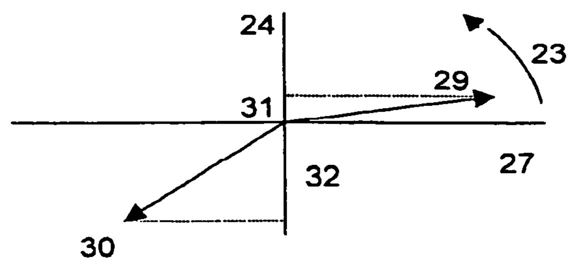


**Figure 3**

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